Natural Gas Vehicles In Hazard Classification Areas

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President – Mansfield Energy Partners

Natural Gas Vehicles Task Force Meeting
January 14, 2014

Who Is Mansfield?

- Supplying, Servicing, and Delivering over 3 Billion Gallons per year (200k bbls a day) one truck load at a time
- Fuel Supply, Distribution, and Delivery in 50 States and Canada
- Ranked by Forbes as #41 of the Top 100 privately held companies in America
- Recognized Innovator
  - Multi-Finalist in 2008, 2009, 2010, 2011 Platts Global Energy Awards
  - Ranked in CIO 100
  - InformationWeek 500, Ranked #1 in Energy and Utilities

CIO 100

platts GLOBAL ENERGY AWARDS 2011 Finalist

Forbes 54 Largest Private Companies — Mansfield Fuels. Simplified.

ERNST & YOUNG Quality In Everything We Do

InformationWeek 500 2013 BUSINESS TECHNOLOGY INNOVATORS

"The largest non-major in the delivered commercial fuel space."
Tom Kloza, Chief Oil Analyst, OPIS

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Developer of Natural Gas Fueling Infrastructure

Serving Bulk Fuel Hauling vertical of the Class 8 Trucking Industry

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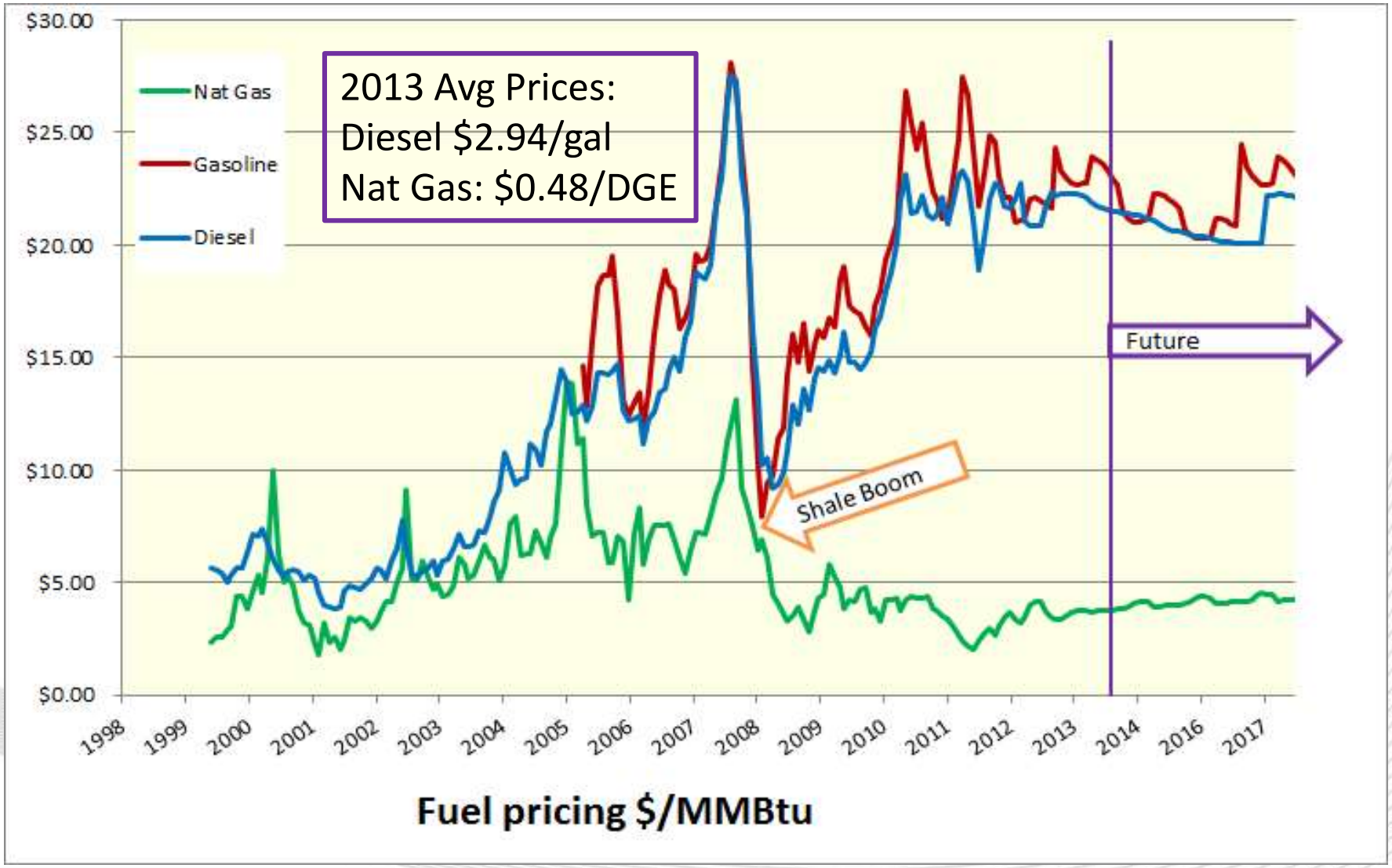
Natural Gas as a Transportation Fuel



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NGV Market in the US – Next Vertical = ?

Total US Market NG Transportation = 275 million gallons 2013

25%

2014 Projected 10 to 13% of Class 8 Truck Build

53%

Almost doubles 2013 NG fuel consumption

UPS Ordered 720 LNG Trucks 100% of their long haul 2014 Order

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The best opportunities for conversion to NG

1) High fuel consumption:
   ≥ 7,000 gal/yr
1) Return to base operations
2) Existing natural gas to site
3) Routes of < 350 Miles
4) ≥ 20 vehicles to base load station investment
5) Suitable engine available and supported by OEM's

Bulk Fuel Hauling

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Hazard Locations

National Electrical Code (NEC)

Areas "*where fire or explosion hazards may exist due to flammable gases or vapors, flammable liquids, combustible dust, or ignitable fibers or flyings*."

Many Class 8 Tractor-Trailers Operate in Areas Classified as Hazard Locations

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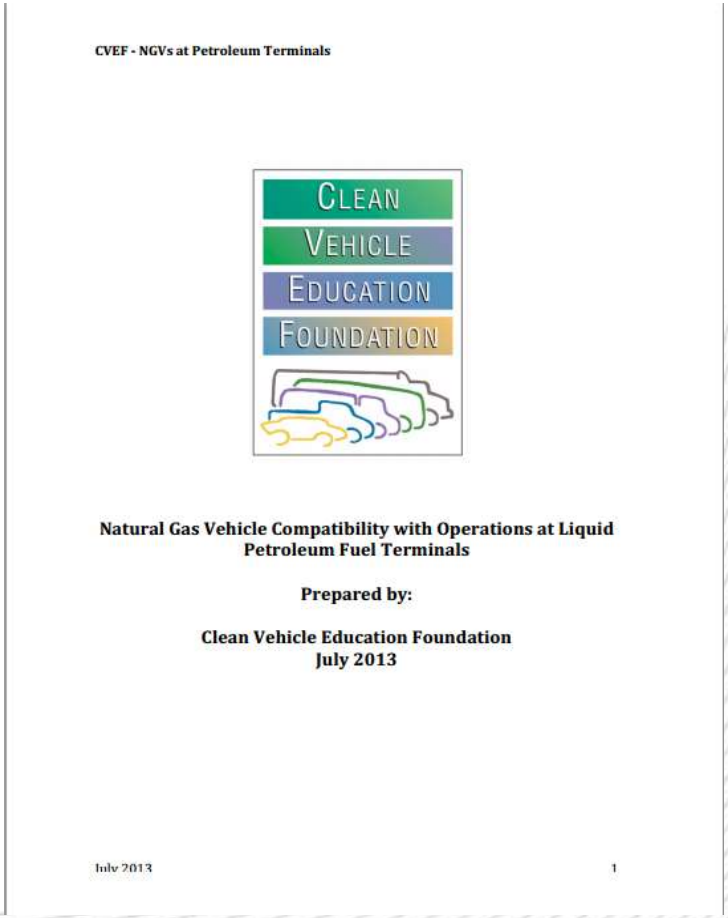
Class I, Div. 2 Fuel Rack Challenge

- ILTA members starting looking for input in 2012
- Longstanding ban on Spark Ignited (SI) Engines under Fuel Racks for some Terminals
  - Dates back 30+ years
- Buckeye – Existing procedures banned SI engines including CNG Tractors
- ILTA feedback and input
- CVEF-led coalition / White Paper


CVEF - NGVs at Petroleum Terminals

CLEAN VEHICLE EDUCATION FOUNDATION

Natural Gas Vehicle Compatibility with Operations at Liquid Petroleum Fuel Terminals

Prepared by:

Clean Vehicle Education Foundation
July 2013

July 2013 1

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Relevance Across Many Industries

This is not just an issue in the Fuels Transportation Industry

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Hazardous Location Classifications

Class I - Gas or Vapor

Class II - Dust

Class III - Fibers and Flyings

Divisions

Division 1 - Normal Conditions

Division 2 - Abnormal Conditions

https://www.osha.gov/doc/outreachtraining/htmlfiles/hazloc.html

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Key Safety Concerns

1. Spark Ignited (SI) Engines as potential ignition source in a Hazardous Area
2. Exhaust System Temperatures as auto-ignition source
3. Potential for natural gas leaks from CNG or LNG tanks
4. Risks of retrofit modifications (vs. OEM)

Do SI Natural Gas engines increase risk relative to diesel CI engines?

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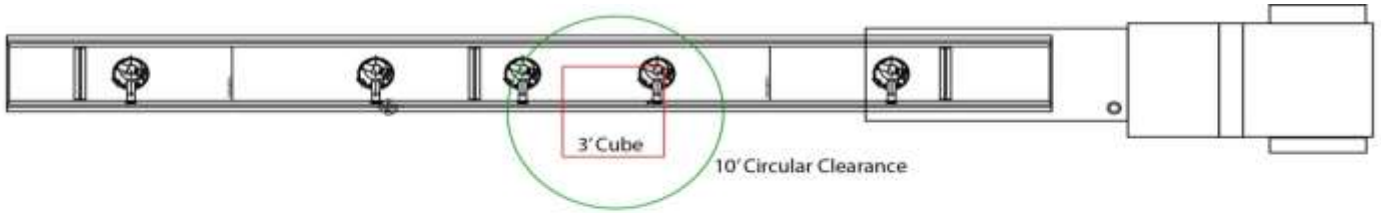
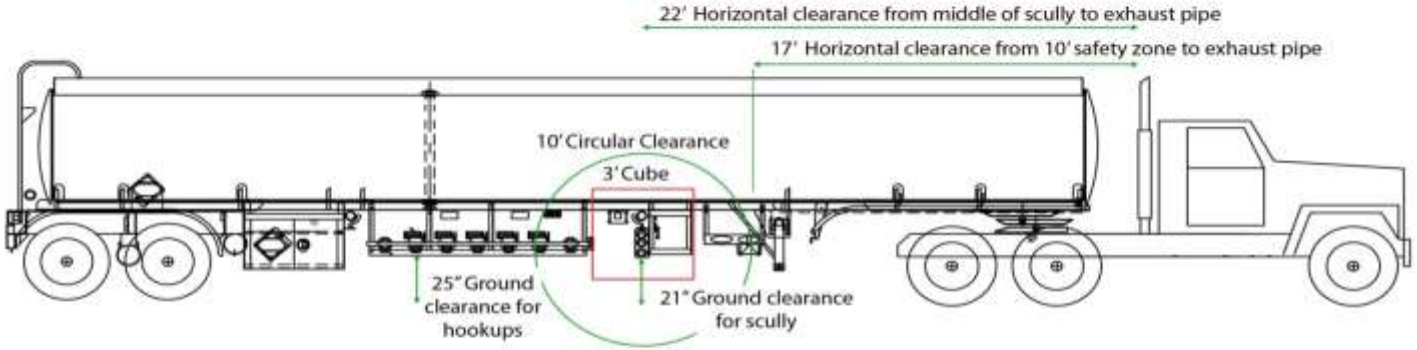
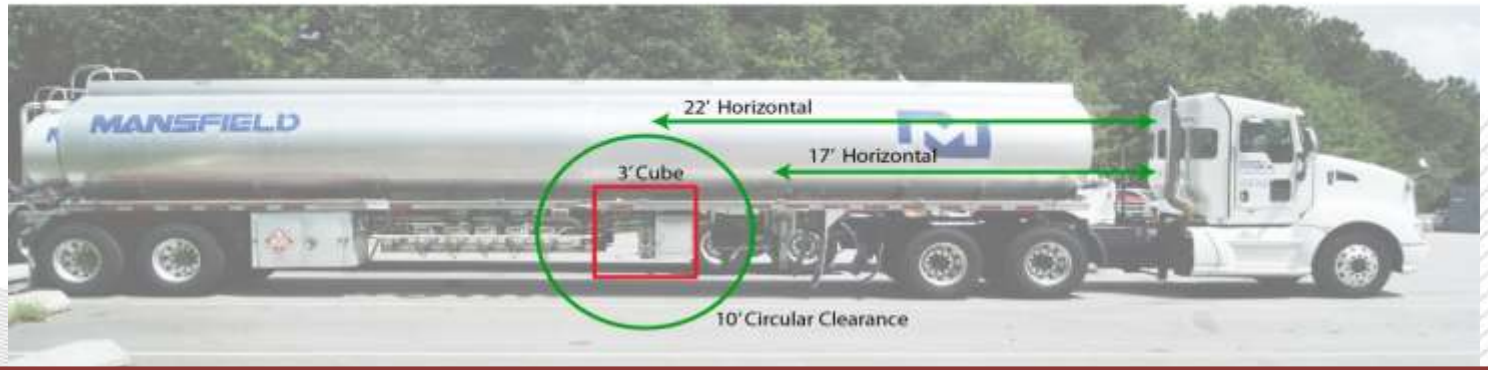
Class I, Div. 2 Area







Exhaust/Engine Components well outside of Class I Area

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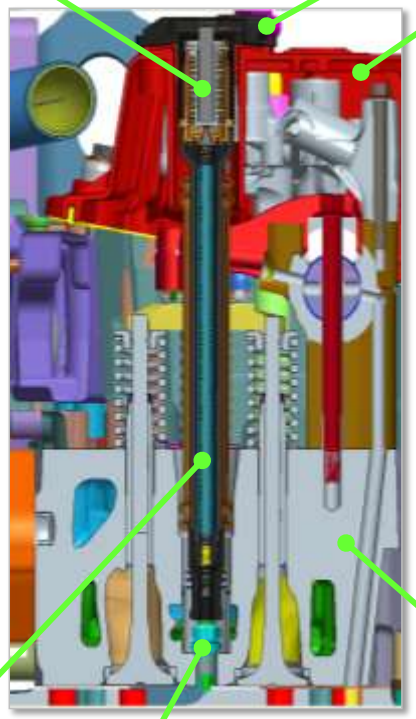
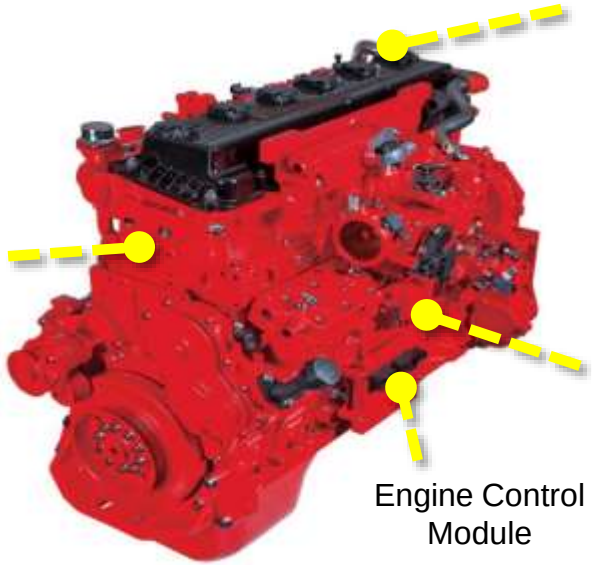
#1 SI Spark/Arc Ignition Source



Cummins ISX-12G Engine



Design of SI NGV engines
No External high voltage wiring source of an arc or spark
Encapsulated design eliminates external spark potential

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#2 Exhaust System Temperatures

Do potentially higher
Exhaust System Component Temperatures
pose an increased risk of Auto-Ignition?

Factors

- Class I, Div. 2 Area location
- Laboratory vs. “Real World”
- Cool-down Rates
- Distance from heat source
- Temperature vs. Time delay

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Exhaust System Temperatures

Parameter	Maximum Temperature (^{0}C/^{0}F)		
	Diesel	HPDI	Spark NGV
DPF skin temperature - normal operation	350/662	350/662	N/A
DPF skin temperature - active regeneration	360/680	360/680	N/A
Exhaust temp at DPF outlet - active regeneration	600/1112	600/1112	N/A
Exhaust temp at DFP outlet - failure mode	975/1787	975/1787	N/A
SCR catalyst skin temperature - normal operation	368/694	368/694	N/A
Exhaust temp at SCR catalyst outlet - normal operation	600/1112	600/1112	N/A
SCR catalyst skin temp - failure mode	325/617	325/617	N/A
Exhaust temp at SCR catalyst outlet - failure mode	800/1472	800/1472	N/A
Catalyst skin temperature - normal operation	N/A	N/A	700/1292
Exhaust temperature at catalyst outlet - normal operation	N/A	N/A	800/1472

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Real-World Auto-Ignition

Material	Autoignition Temperature °F	Notes
Diesel	350-625	**Laboratory - ASTM**
Diesel	**>1200**	Heated catalytic converter. No ignition, test stopped at 1200 degrees F
Diesel	950-1000	Heated pipe
Diesel	1010-1125	Recessed stainless steel plate
B100 (Biodiesel)	705-840	Recessed stainless steel plate and fluid spray
B20 (Biodiesel)	980-1300	
E-diesel (Ethanol blend)	1265-1400	

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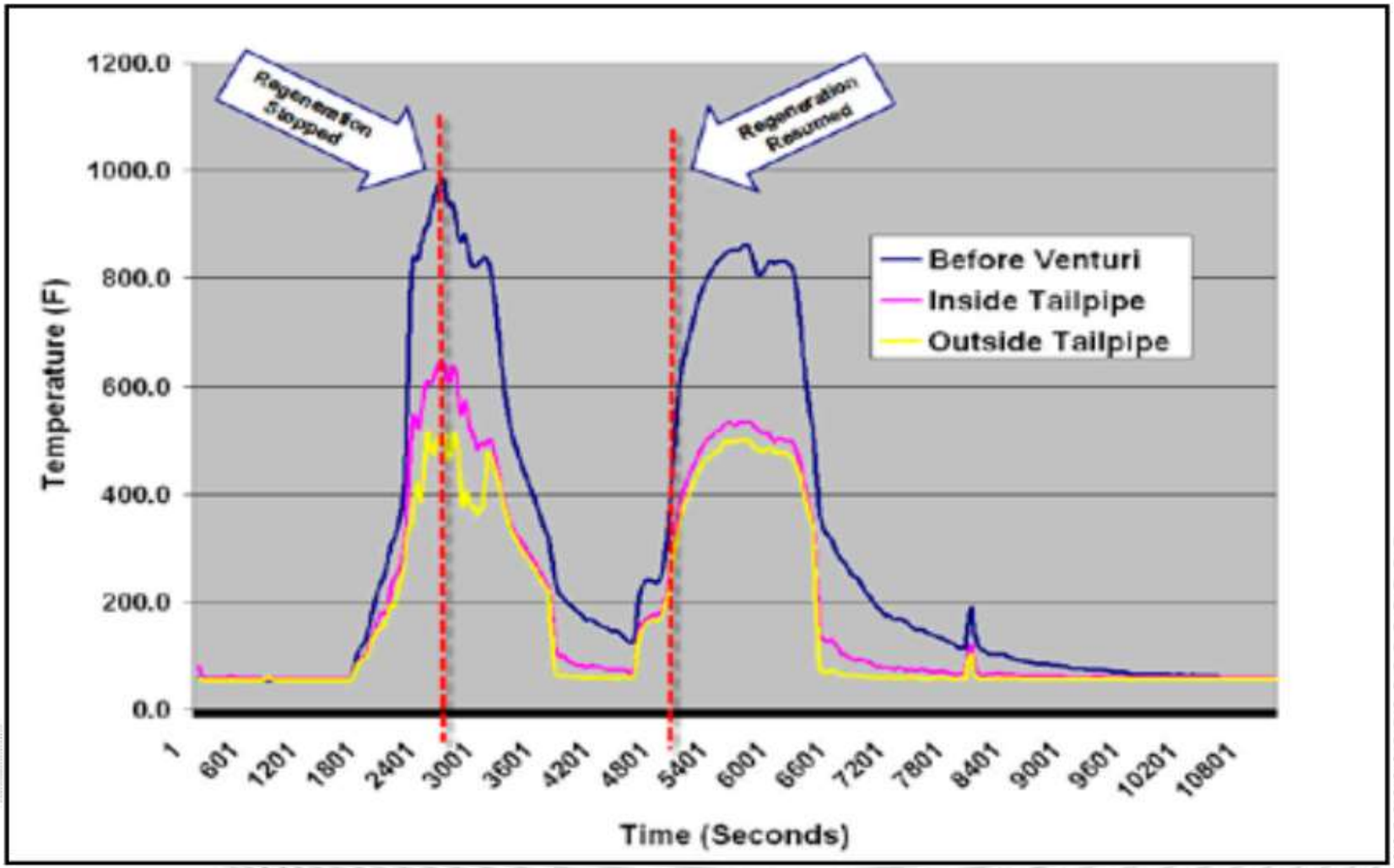
Cool-down Rate



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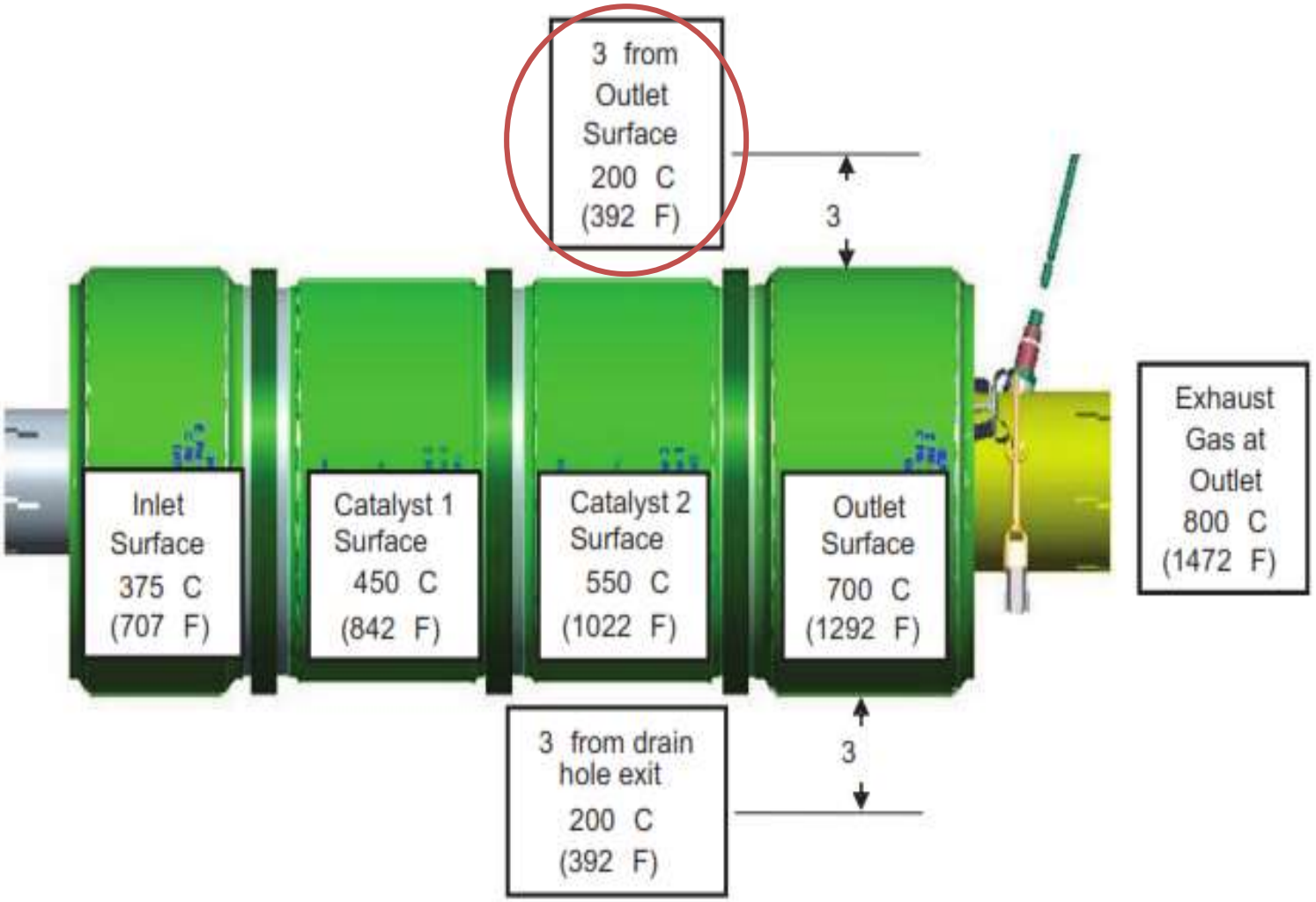
Temperature vs. Distance

Maximum Surface and Gas Temperatures of a Standard Insulated Catalyst during Normal Operations



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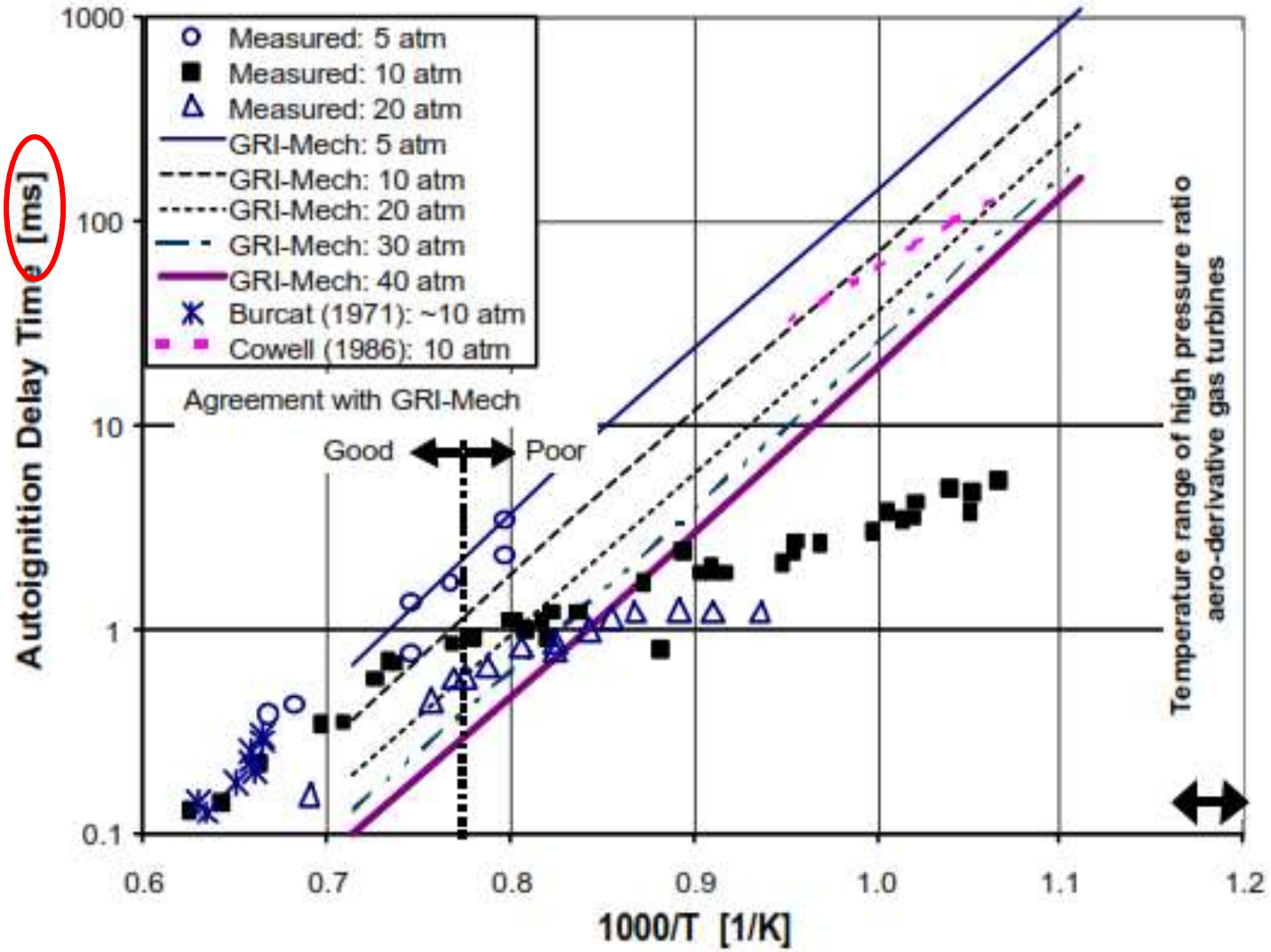
Autoignition Time Delay



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Exhaust Temperature Mitigation

- Components outside of Class I, Div. 2 area
- Temperatures (both diesel and CNG)
  - Above laboratory auto-ignition temperatures
- Auto-ignition time delay insignificant w/ temp
- Real World Auto-Ignition well above ASTM
- Cool Down rates: High
- Temp vs. Distance: Large Gradient

Autoignition Risk is Comparable to Diesel

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#3 Nat Gas Leak Potential

Will CNG or LNG Vent when “Under the Rack”?

- Cylinder Design, Testing, and Operation
- Thermal Relief Valve (CNG) @ 219°F
- CNG Odorized (can smell at 1/5 LEL)
- LNG has Methane detection system
- Pressure Relief (LNG)
- LNG Boil Off – 7-10 days

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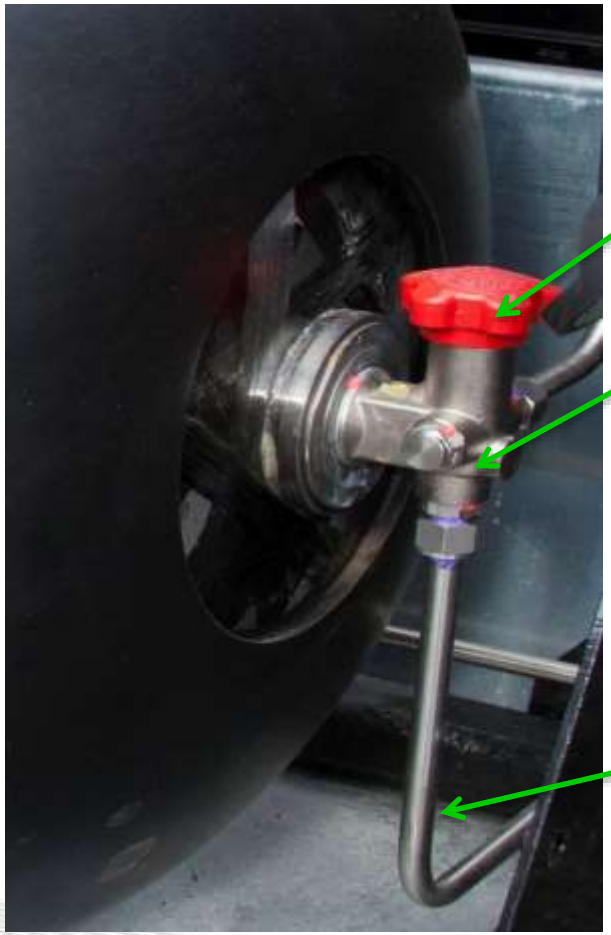
CNG Thermal Pressure Relief Device



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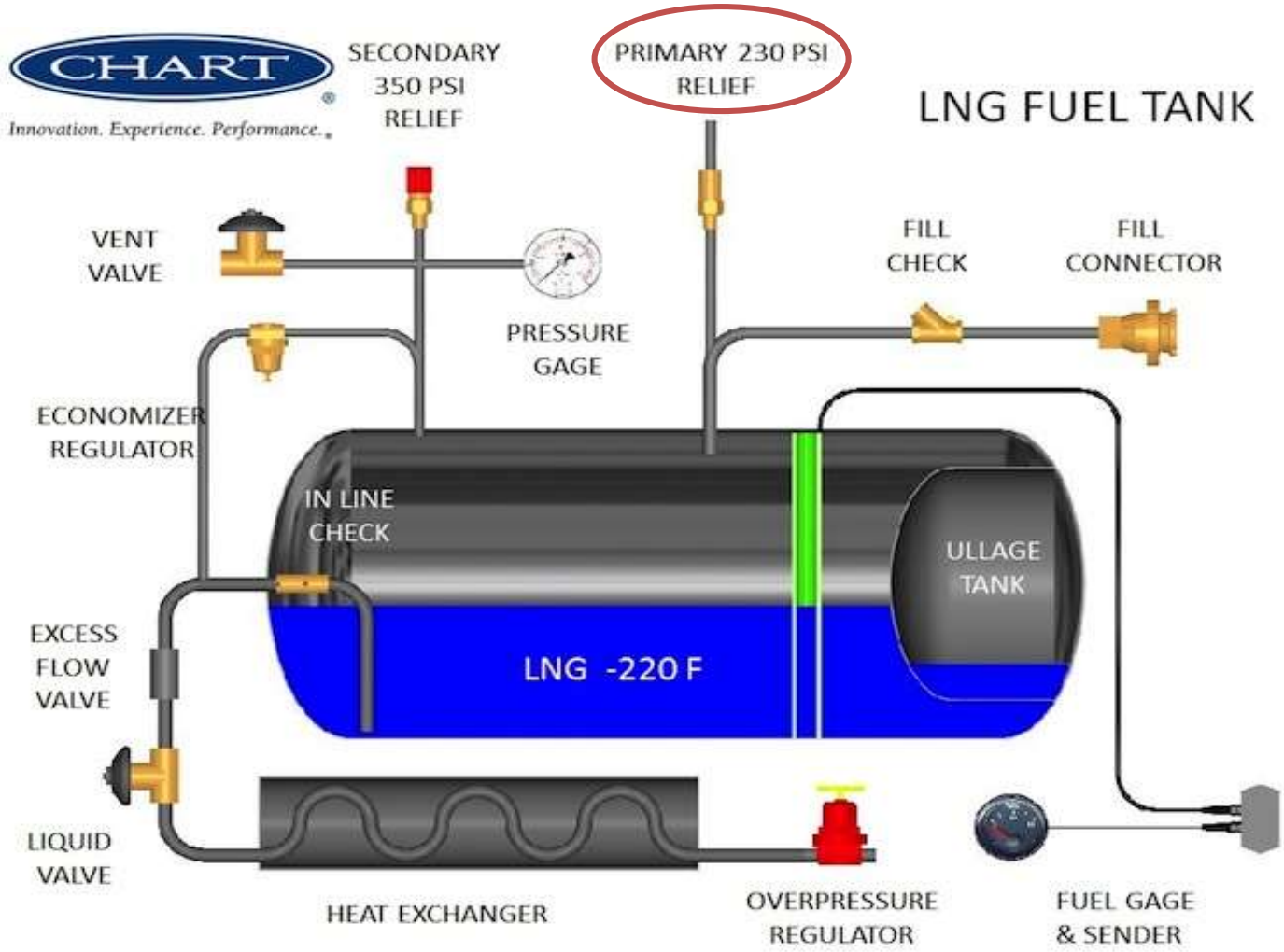
LNG Fuel Tank



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Tank Leak Mitigation

- Design itself mitigates leak potential
- Testing and Periodic Inspection
- Odorant or Methane Detection in unlikely event of leak
- Neither LNG nor CNG tanks are designed to vent under normal operations at the loading rack.
  - CNG tank involved in a fire before the PRD operates
  - LNG truck parked at the rack for 7-10 days for pressure relief to lift

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Conclusions

- Nat Gas engines no greater risk of spark
- Exhaust temperatures pose similarly small risk profile
- Low risk of tank failure:
  - Stringent design/testing standards
- OEM NGVs considered inherently safety designed and built

SI Natural Gas engines pose comparable risk compared to diesel CI engines

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Questions?

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